TABLE I.—Plate with angle of emergence in air 53° 24′.

Liquid.	μ_D.	$\alpha-\theta$.	α.	Δ.
Carbon bisulphide......	1·6473	24° 15′	53° 26′	+2′
α-Bromonaphthalene....	1·5341	21 50	53 22½	−1½
Benzene	1·4970	21 0	53 27½	+3½
Turpentine............	1·4726	20 20	53 20½	−3½
Olive oil..............	1·4673	20 12	53 21	−3
Glycerol..............	1·4634	20 10	53 28½	+4½
Chloroform	1·4439	19 35	53 19½	−4½
Alcohol..............	1·3561	17 2	53 15	−9
Water....	1·3327	16 21	53 22	−2

TABLE II.—Plate with angle of emergence in air 54° 42′.

Liquid.	μ_D.	$\alpha-\theta$.	α.	Δ.
Carbon bisulphide......	1·6473	24° 58′	54° 38½′	−3½′
α-Bromonaphthalene....	1·5341	22 35	54 44½	+2½
Benzene..............	1·4970	21 41	54 44½	+2½
Turpentine............	1·4726	21 0	54 37	−5
Olive oil..	1·4673	20 56	54 45	+3
Glycerol..............	1·4634	20 51	54 47½	+5½
Chloroform...........	1·4439	20 17	54 42	0
Alcohol...............	1·3561	17 45	54 48½	+6½
Water................	1·3327	16 54	54 37	−5

that, as would of course be expected, the most accurate results are obtained with liquids of high refractive index, which give comparatively large values of $\alpha-\theta$. By determining the values of $\alpha-\theta$ for each of two optic axes of a given crystal plate, it can easily be ascertained with what amount of accuracy the plate has been cut perpendicularly to the bisectrix.

The principle of the method here described may very possibly be advantageously employed in other branches of optical investigation.

"On Colour Photography by the Interferential Method." By G. LIPPMANN, Professor of Physics, Faculty of Sciences, Paris. Communicated by Sir JOSEPH LISTER, Bart., P.R.S. Received April 14,—Read April 23, 1896.

Colour photographs of the spectrum, or of any other object, are obtained by the following method. A *transparent* photographic film of any kind has to be placed in contact with a metallic *mirror* during

exposure. It is then developed and fixed by the usual means employed in photography, the result being a *fixed* colour photograph visible by reflected light.

The mirror is easily formed by means of mercury. The glass plate carrying the film being inclosed in a camera slide, a quantum of mercury is allowed to flow in from a small reservoir and fill the back part of the slide, which is made mercury-tight. The plate is turned with its glass side towards the objective, the sensitised film touching the layer of mercury. After exposure, the mercury is allowed to flow back into its reservoir, and the plate taken out for development.

The only two conditions necessary for obtaining colour, transparency of the film and the presence of a mirror during exposure, are physical conditions. The chemical nature of the photographic layer has only secondary importance; any substance capable of giving, by means of an appropriate development, a fixed colourless photograph, is found to give, when backed by the mirror, a fixed colour photograph.

We may take, for instance, as a sensitive film, a layer of albumeno-iodide of silver, with an acid developer; or a layer of gelatino-bromide of silver, with pyrogallic acid, or with amidol, as developers. Cyanide or bromide of potassium may be as usual employed for fixing the image. In a word, the technics of ordinary photography remain unchanged. Even the secondary processes of intensification and of isochromatisation are employed with full success for colour photography.

The photographic films commonly in use are found to be opaque, and formed, in fact, by grains of light-sensitive matter mechanically imprisoned by a substratum of gelatine, albumen, and collodion. What is here wanted is a fully transparent film, the light-sensitive matter pervading the whole of the neutral substratum. How can such a transparent film be realised? This question remained insoluble to me for many years, so that I was debarred trying the above method when I first thought of it. The difficulty, however, is simply solved by the following remark. It is well known that the precipitation of a metallic compound, such as bromide of silver, does not take place in the presence of an organic colloid, such as albumen, gelatine, or collodion. In reality, the metallic compound is formed, but remains invisible; it is retained in a transparent modification by the organic substances. We have only, therefore, to prepare the films in the usual way, but with a stronger proportion of the organic substratum; the result is a transparent film. By mixing, for instance, a gelatinous solution of nitrate of silver with a gelatinous solution of bromide of potassium, no precipitate is formed, and the result is a transparent film of dry gelatine containing 15 and even 30 per cent. of the weight of bromide of silver.

The colours reflected by the film are due to interference: they are of the same kind as those reflected by soap bubbles or by Newton's rings. When a ray of definite wave-length falls on the sensitive plate, it is during exposure reflected back by the mirror, and then gives rise to a set of standing waves in the interior of the film, the distance between two successive loops being equal to half the wave-length of the luminous ray. This system of standing waves impresses its periodical structure on the film. The photographic deposit, therefore, takes the form of a grating, a continuous grating, perfectly adapted for reflecting the particular luminous ray which has given it birth.

This theory can be subjected to experimental proof. If we examine a photograph of the spectrum, or any other object by white light, we observe the following facts. (1.) Colours are seen in the direction of specular reflection, and are invisible in every other direction. (2.) The colours change with the incidence; the red changing successively to green, blue, and violet, when the incidence grows more oblique. The whole image of the spectrum is displaced, and gradually passes into the infra-red region. (3.) If the film be gradually moistened, the colour changes in the opposite direction, from violet to red. This phenomenon is due to the swelling up of the gelatine or albumen, causing the intervals between the elements of the grating to become larger. The smaller intervals, corresponding to violet and blue light, gradually swell up to the values proper to red and infra-red waves. A photograph immersed in water loses all its colours, these appearing again during the process of drying. For the same reason, a freshly prepared plate has to be dried before the correct colours can be finally seen.

We have now to consider the case of compound colours, and to generalise the former theory, which is only applicable to the action of simple rays. I beg to subjoin an abstract of this generalised theory. It will be seen that if a compound ray of definite composition impresses the plate, it gives rise during exposure to a definite set of standing waves, which impress their structure on the film, and impart to the photographic deposit a corresponding definite form. Though very complex, this can be described as made up of a number of elementary gratings, each corresponding to one of the simple rays which contribute the impressing light. When examined by white light, the reflected ray is shown to have the same composition as the impressing ray; white light, for instance, imparts to the photographic deposit such a structure that it is adapted to reflect white light.

The only *a priori* condition for the correct rendering of compound rays, is a correct isochromatisation of the film. This, again, can be practically effected by known processes, such as have been indicated by E. Becquerel, Vogel, Captain Abney, and others.

As a verification of this theory, I beg leave to project on the screen a series of colour photographs, representing natural objects: pictures on stained glass, landscapes from nature, flowers, and a portrait from life. Every colour in nature, including white, and the delicate hue of the human complexion, is thus shown to be reflected by a correctly developed photographic film.

It is to be remarked that, as in the case of the spectrum, the colours are visible only in the direction of specular reflection. If I had tried to touch up these photographs by means of water colours or other pigments, these would be made apparent by slightly turning the photograph; these pigments remaining visible under every incidence, they would thus be seen to stand out on a colourless background. Thus the touching up or falsifying by hand of a colour photograph is happily made impossible.

"Note on Photographing Sources of Light with Monochromatic Rays." By Captain W. de W. Abney, C.B., D.C.L., F.R.S. Received March 31,—Read April 30, 1896.

In a paper "On the Production of Monochromatic Light," communicated to the Physical Society, and read on the 27th June, 1885, and which appears in the 'Philosophical Magazine' for August in that same year, I stated that by the apparatus then described a monochromatic image of the sun could be thrown upon the screen. In the same periodical for June of the same year, Lord Rayleigh described a plan for obtaining a monochromatic image of an external object, in which a concave lens was placed behind the slit of a spectroscope to produce an image of the object in monochromatic colour, the object being viewed through an aperture placed in the spectrum produced by the apparatus. I had been working independently at the subject at the same time, and my object was to get an image on a screen or photographic plate rather than to use the apparatus for visual observation. When a lens is placed behind the spectrum in the manner described in the paper above referred to, a white image of the prism can be obtained on a screen placed at some distance from the lens, and the size of the image can be increased or diminished according to the focal length of the lens, and its distance from the spectrum. Evidently, then, if an image of a luminous object can be cast on the surface of the prism, and a slit be placed in the spectrum, the image of the luminous object will be seen of the colour of the light passing through the slit. There are devices adopted at the present time for photographing the sun with light of various wave-lengths, but, as far as I am aware, they depend upon moving the image of the sun across the slit of the spectroscope, the